Relevance of a Polymer-Induced Liquid-Precursor (PILP) Mineralization Process to Biomineralization and the Development of Biomarkers

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The ability to establish biomarkers for biologically-produced minerals requires an understanding of the processes involved in biomineralization. Our laboratory has been studying a polymer-induced liquid-precursor (PILP) process which we believe may play a key role in the morphogenesis of wide variety of biominerals, ranging from microbes to vertebrates. The mimetic polypeptide sequesters ions and induces liquid-liquid phase separation of droplets of a metastable, hydrated amorphous mineral precursor. More and more evidence in the recent literature suggests that many biominerals may be formed via an amorphous precursor route. We take this one step further by proposing that a key role of the polymer is that it entraps high levels of water in the amorphous precursor, imparting it with fluidic character. Because the mineral precursor is initially fluidic, it takes the shape of its container, and upon solidification, forms spatially-delineated single-crystals. Minerals can be deposited as films or coatings, "molded" via templating within organic matrices, or mineral "fibers" can be grown under physiological conditions. Non-equilibrium morphologies are the hallmark of biomineralization, and the non-specificity of the polymer-mineral interactions during the PILP process suggests that it could be involved in a variety of biomineral systems, and in fact, this simple process could conceivably lie at the foundation of the evolutionary development of mineralizing organisms. Impurity and isotopic compositions are commonly used as geologic signatures. The PILP process causes dramatic alterations to the composition of minerals because impurities become entrapped in the precursor phase (e.g. high Mg-bearing calcite). The defect textures of crystals formed via the PILP process (i.e. those caused by shrinkage stresses) are generally different from inorganic or geologic precipitates, and thus could be used as mineralogical signatures for the detection of biogenic components within extraterrestrial rocks or other disputed biomineralogical samples. Both the shape and texture of the crystals deposited by the PILP process, as well as impurity incorporation, exhibit features that are reminiscent of mineral crystals solidified from the melt; yet they are generated at room temperature. Such issues are central to the debate regarding the mars meteorite ALH 84001, in which the geological and biological basis of interpretation of the data seem to be in contradiction.